

## TEST RESOLVER MANAGEMENT SYSTEM

### Field of the Invention

5       The present invention relates to a system for processing answers to test questions.

### Background of the Invention

10       The scoring of test answer sheets involves complex problems. These test answer sheets typically include a series of response positions such as, for example, "bubbles," ovals, or rectangles. A person taking a test would, for example, darken in an appropriate oval with a pencil to answer a multiple choice question. These test answer sheets may also include handwritten answers, such as  
15       essay or short answer questions. Systems for scanning and scoring the bubbles on such answer sheets are known in the art. Increased difficulties are encountered, however, when such answer sheets either include other types of answers, such as handwritten answers, or cannot be machine graded.  
20       For example, if the student has failed to include his or her name on the test answer sheet, the system may be unable to machine score the test answer.

25       The goals in scoring test answers that cannot be machine scored include efficiency and consistency. These test answer sheets are typically scored by test resolvers either by manually scoring the physical test answer sheet

or scoring an electronic representation of the test answer sheet on a computer. Ideally, the scores provided by the various test resolvers for a particular test question should be consistent, since the scores are used in

5 comparing performance of the students against one another.

In addition, a test resolver should ideally work efficiently so as to maintain consistently high scoring rates. The test resolver should not have such a high

10 scoring rate that the consistency or quality of scoring significantly declines; likewise, the test resolver should not have such a low scoring rate that the too few answer sheets are being scored. This manual scoring of test answer sheets, however, makes it difficult to monitor the consistency of scoring among the various test resolvers.

15 In many situations, test resolvers actually travel to a particular location so that all test resolvers may simultaneously score test answer sheets. Requiring the test resolvers to travel to a given location is inconvenient for the resolvers and expensive for those who  
20 administer the tests. Furthermore, tracking the performance of test resolvers against both their own performance and the performance of other resolvers can be very difficult with a manual scoring environment.

The process of resolving test questions is  
25 currently done manually, and this presents problems. A resolver is manually presented with the actual test answer

5 sheets for scoring. This process is relatively inefficient, since the resolvers must score the answer sheets one at a time and in the order in which they are presented. Also, manual scoring systems do not have the capability to efficiently gather and categorize the test answers for subsequent analysis. Therefore, with a manual system it is very difficult to determine how teaching methods should be changed to decrease, for example, the number of incorrect answers.

10 A need thus exists for a system that promotes and achieves consistency and efficiency in scoring or resolving of tests.

#### Summary of the Invention

15 The present test resolver management system facilitates consistent, accurate, and high quality scoring of test answers. A collaborative scoring sub-system allows two test resolvers to score the same test answer and resolves potential discrepancies in the scores provided by  
20 the resolvers.

The system also has the capability to use quality items to monitor a resolver's scoring performance. The system transmits a quality-control test item, having a known score, to a test resolver. After receiving a score  
25 from the resolver, the system compares the known score with

the resolver's score and can generate a quality profile for the resolver.

The system also provides performance feedback to test resolvers by monitoring the scoring rates of the  
5 resolvers. If a resolver's scoring rate, in comparison to another scoring rate, contains a discrepancy, the system can report the discrepancy. The system can also recommend breaks to a resolver, or provide a resolver with  
10 diversionary activities, in response to a discrepancy in scoring rates. The system also has the capability to route test answers to resolvers based on classifications of resolvers and persons who generated the test answers. Monitoring and selecting resolvers based on classifications promotes fair and consistent scoring of test answers.  
15 Finally, the system provides for an on-line scoring guide to dynamically provide a test resolver with scoring rules for a test answer displayed to the resolver.

#### Brief Description of the Drawings

20 FIG. 1 is a diagram of a network that incorporates the present invention.

FIG. 2 is a block diagram of a portion of the network shown in FIG. 1.

FIG. 3 is a block diagram of the scanning  
25 configuration in the network of FIG. 1.

FIG. 4 is a block diagram of the server in the network of FIG. 1.

FIG. 5 is a flow chart of receiving and processing of test items.

5           FIG. 6 is a flow chart of multiple item scoring.

FIG. 7 is a flow chart of categorized (special) item reporting.

FIGS. 8-10 are a flow chart of collaborative scoring.

10           FIG. 11 is a flow chart of quality item processing.

FIG. 12 is a flow chart of resolver monitoring and feedback.

15           FIG. 13 is a flow chart of an on-line scoring guide system.

FIG. 14 is an example of a user interface for use with multiple item scoring.

#### Detailed Description of the Preferred Embodiment

20           In the following detailed description of the preferred embodiment, reference is made to the accompanying drawings which form a part hereof and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. This embodiment is described  
25   in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that

other embodiments may be utilized and that structural or logical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting  
5 sense, and the scope of the present invention is defined by the appended claims.

#### HARDWARE CONFIGURATION

FIG. 1 illustrates an example of a hardware  
10 configuration for a network that incorporates the present invention. This configuration is shown as an example only; many different hardware configurations are available, as recognized by one skilled in the art, for implementing the software processing functions described below. The network  
15 shown comprises a mainframe computer 20 interfaced through a backbone token ring to a plurality of RISC servers 11, 12 and 13. Each RISC server is interfaced to a token ring that contains work stations and scanners. The RISC server 11 is connected in token ring 1 to scanners 14 and work  
20 stations 19. The RISC server 12 is connected in token ring 2 to scanner 15 and work stations 18. The RISC server 13 is connected in token ring 3 to scanners 16 and work stations 17. The mainframe computer 20 is also connected to a high capacity printer 22 and a low capacity printer 21  
25 for printing reports of stored data within the system.

The system uses the scanners for reading in test answer sheets. These test answer sheets may comprise, for example, test forms with "bubbles" or ovals representing possible answers, handwritten essays, or other various types of written or printed information. After receiving the scanned test data, the system within the RISC servers can process those scanned test answer sheets to generate test items of interest from the answer sheets. A test item is, therefore, an electronic representation of at least a portion of a test answer sheet. The system may distribute these test items to the work stations for on-line scoring. A test scorer at a work station can then score the test item and enter a test score. The system receives the test scores via the network and the RISC servers and distributes the scores to an appropriate computer for subsequent printing and reporting; the appropriate computer may include, for example, the mainframe computer 20 or a server. The system may also transmit the test scores to, for example, a disk or telephone line.

FIG. 2 is a more detailed block diagram of a portion of the network shown in FIG. 1. As shown in FIG. 2, the scanning units shown in FIG. 1 typically comprise a scanner 25 interfaced to a computer 24 and personal computer (PC) 26. FIG. 3 shows a more detailed block diagram of a scanning unit. The scanner 25 contains a camera 31 for optically reading in a test answer sheet, and

further contains optical mark recognition (OMR) logic 32 for processing the scanned data received from camera 31. The PC 26, preferably implemented with a high performance 486-level PC, contains a frame buffer 23 for receiving the scanned image data from the scanner 25.

The computer 24, preferably implemented with an HP 1000, is interfaced to the scanner 25 and PC 26 for controlling the operation of the scanning unit. The computer 24 is optional; the system may alternatively be configured such that all of the functionality of the computer 24 is within the PC 26. The computer 24 controls the scanner via the OMR logic 32 and thus controls when image data is scanned in and subsequently transferred to the PC 26. The PC 26 essentially acts as a buffer for holding the image data. The computer 24 further controls when the PC 26 will interrogate the image data for transmission to a server 27 for subsequent processing and scoring. The PC 26 can also electronically remove or "clip" an area of interest from the image data, which represents at least a portion of the scanned test answer sheets.

Examples of two systems for storing and extracting information from scanned images of test answer sheets are shown in U.S. Patent Nos. 5,134,669 and 5,103,490, both of which are assigned to National Computer Systems, Inc. and are incorporated herein by reference as if fully set forth.



The server 27 receives the image data, which includes test items, and provides for processing and control of the image data. This portion, which may be a test item, is then distributed to the work stations 28, 29 and 30 for subsequent scoring. A test resolver (scorer) at the work station typically receives the test item, performs the scoring, and transmits the score to the receiving computer.

FIG. 4 is a block diagram of the hardware and software functions in a server in the network of FIG. 1. A scan control module 31 interfaces with the scanner PC 26 and receives the image data. The image data is stored in a raw item database 36. The central application repository (CAR) 33 typically stores document definitions and handling criteria. The document process queue 37 functions as a buffer into a main processing module 45 in server 27.

The main processing module 45 controls the processing of test items. It controls the transmission of test items to the work stations for scoring and the transmission of scores to the mainframe computer 20. The main processing module 45 also monitors the performance of the test resolvers to maintain consistent and efficient resolving of test items, as is explained below.

The main processing module 45 typically contains the following basic functions, which are controlled by system management module 32. A work flow module 38

receives image data from the database 36 and controls the flow of data into an edit process module 39. The edit process module 39 may perform machine scoring of the test items. For those test items which cannot be machine  
5 scored, or possibly for other test items, the system transmits such test items to the job build function 40. The job build function 40 determines what type of subsequent scoring is required for the test item and, for example, which work station will receive the test item. A  
10 job send module 41 receives the test item and transmits it to a router 42, which in turn transmits the test item to a send/receive communication module 43. Edit work module 34 and edit server module 35 control the flow of test items into and out of server 27. Incoming data, such as test  
15 answers from the work station, are transmitted through modules 34 and 35 to a job receive module 44. The job receive module transmits the data to the edit process module 39 for subsequent storage within the database 36.

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#### SOFTWARE PROCESSING

FIG. 5 is a flow chart of typical scanning and processing of test and answer sheets. The document processing system receives the test answer sheets, or other documents, at step 50 and performs initial clerical  
25 preparation of the documents (step 51) for scanning at step 52. The system at step 52 scans the documents for OMR and

other image data. The system may then process the OMR bubbles at step 53 and store the data in the work-in-process storage (WIP) at step 54. The system at step 56 can "clip" areas of interest from the scanned image. The  
5 step of "clipping" involves electronically removing, typically in software, a portion of the test item or scanned image. These "clipped" areas may comprise any portion of a test answer sheet; for example, a handwritten essay or selected response positions. The system may also  
10 receive image data directly from foreign sources, magnetic or electronic, and store the data in raw item database 36. Subsequent operations on the data are the same regardless as to the source of the data. After "clipping" areas of interest from the image, the system stores the test items  
15 at step 57 in the work-in-process storage 55.

The system waits at step 55 until it determines that a test item is ready to be resolved or scored. If multiple resolution items are present within the image data, as determined at step 59, then the system sends the  
20 test item to multiple item processing at step 63. Otherwise, the system performs other resolution processes on the data at step 60 and stores the result in work-in-process storage 55 at step 61. Other resolution processes may include, for example, machine scoring, raw key entry,  
25 and analytic resolving.

Analytic resolving or scoring may include, for example, map comparisons such as bit-mapped comparisons between two test items. The map comparisons allow a test resolver to compare, for example, the answers of a  
5 respondent over time to track the respondent's progress. For example, the analytic scoring may involve comparing two hand-drawn circles by the respondent to determine if the respondent's accuracy in drawing circles has improved over time. Analytic scoring may also include, for example,  
10 circling or electronically indicating misspelled words and punctuation errors in an answer such as an essay.

#### Multiple Item Scoring

FIG. 6 is a flow chart of typical multiple item  
15 processing. The system at step 64 typically first fetches a multiple item image from the work-in-process storage. The image is stored in a multiple item display memory 65 and a multiple item display storage 69 for subsequent display to a resolver. The system continues to receive  
20 multiple items until either the item display is full, as determined at step 66, or no more multiple items are present as determined at step 68. As long as the display is not full and additional multiple items are present, the system preferably scans the work-in-process storage at step  
25 67 for additional items. When the multiple item display is full or no more multiple items are present, the system

sends the compiled multiple items to a resolver at step 70 and displays the multiple test items on the resolver display 71.

5       The system typically transmits test items to a particular resolver based upon the resolver's resolution expertise. For example, a certain resolver may be assigned to score all of the test items relating to science questions. Resolution expertise may also comprise, for example, math, english, history, geography, foreign  
10       languages, or other subjects.

      An example of an interface on the resolver display is shown in FIG. 14. The interface typically comprises a plurality of cells 74, with each cell containing one test item to be resolved. After displaying the multiple items  
15       in the cells of the resolver display, the system allows the resolver at step 72 to score the multiple items. A test resolver would typically indicate the score of the answers by using a "mouse," light pen, touch screen, voice input, or some other type of cursor control or input device.

20       In the example shown in FIG. 14, the correct answer is "four" and the incorrect answers are indicated by the shading. Alternatively, a resolver could indicate the correct answers. The advantage of the multiple item system arises from the simultaneous display of test items in the  
25       cells 74, which allows a test resolver to quickly score many test items and thus achieve a faster response time in

comparison to the display and scoring of only a single test item at a time. Even the simultaneous display of two items increases response time. As the matrix of cells increases, the simultaneous display of test items achieves a  
5 significant increase in response time and resolver attention and focus.

After scoring or resolving, the system receives the results at step 73 for subsequent storage in work-in-process storage 55. A test resolver typically transmits  
10 the results of resolving all displayed test items in the cells as a single unit for batch processing.

#### Categorized Item Reporting

FIG. 7 is a typical flow chart of categorized  
15 (special) item reporting. Categorized item reporting allows the system to both group answers according to predefined categories and monitor processes used by the students or test-takers in arriving at a given answer. The categories in which test answers may be grouped include,  
20 for example, incorrect answers and correct answers within a curriculum unit within an instructional grouping and requested time frames; for example, all of the incorrect math answers in a particular instructor's class during the previous school year. Other groupings are possible  
25 depending upon the needs of the test resolvers and

instructors who teach the material to which the test relates.

In addition, the system may merge an image of a test item with the corresponding score. In order to facilitate teaching of material to which the test relates, the system typically merges a test item representing an incorrect answer with the corresponding score. By reporting the actual test item, an instructor may gain insight into a thought process used by the student in arriving at the incorrect answer. Therefore, by having some knowledge of why a student answered a test question incorrectly, an instructor can take measures to change or modify teaching strategies to correct the situation.

The categorized item reporting normally comprises the following functions. The system at step 75 scans the work-in-process storage for items that are ready to be reported. If test items are ready for reporting, as determined at step 76, the system processes the data at step 77 for generating an appropriate report of the data. At step 78, the system scans the central application repository for definitions of categorized (special) items. As special items are available for reporting, as determined at step 79, the system retrieves the special items at step 80 and can merge it at step 81 with other report information, such as the corresponding test items, as

explained above. The system then distributes a report at step 82, which can be a printed report.

### Collaborative Scoring

5                FIGS. 8-11 are a flow chart of a typical collaborative scoring system. The collaborative scoring system provides for functions to achieve fairness and objectivity in resolving of test items. The collaborative scoring, for example, allows two resolvers to score the  
10                same item and, if the answers are not within a certain predefined range, provides for subsequent processing to resolve the discrepancy.

                 The system at steps 83 and 84 determines if items are available for scoring. At step 85, the system receives  
15                collaborative scoring requirements from the database and determines at step 86 if collaborative scoring is required. Examples of collaborative scoring requirements are illustrated below. If collaborative scoring has been specified, the system retrieves the item to be scored from  
20                the work-in-process database at step 87 and sends the item to resolvers 1 and 2 at steps 88 and 91.

                 The system is further able to choose resolvers according to selection criteria at steps 89 and 90. The selection criteria of the resolvers for scoring answers may  
25                include, for example, race, gender, or geographic location. The ability of the system to assign test resolvers to score



particular test items provides the basis for increased fairness and consistency in the scoring of tests. For example, the system may assign test resolvers to test items based on the same racial classification, meaning that the  
5 test resolver has the same racial classification as the student or respondent whose test the resolver is scoring. The system may also assign test resolvers to test items based on a different, forced different, or preferred blend of classifications. The system monitors consistency in  
10 scoring based on the selection criteria and, more importantly, can change the selection criteria to ensure consistent and fair scoring of test items.

FIG. 9 is a flow chart showing additional typical functions of the collaborative scoring. At steps 92 and  
15 93, the system displays the items to resolvers 1 and 2 for scoring. The system may further track the average scores of resolvers and not send the same test item to two resolvers who have provided average scores within a predefined range. This also helps to achieve consistency  
20 in scoring. For example, if two scorers each have provided high average scores in the past, as determined by the system, these two scorers should preferably not be collaboratively scoring the same test items, since it could result in "inflated" scores for particular test items.

25 The system records the scores from resolvers 1 and 2 at steps 94 and 95, respectively, and stores such scores

in a temporary storage 96. At step 97, the system compares the scores according to criteria specified in the central application repository. Such criteria may include, for example, requiring that the scores be within a predefined percentage of each other. If the scores meet the criteria as determined at step 98, the system records the score in the work-in-process database at step 46. Otherwise, if the scores do not meet the criteria, the system determines at step 99 if the scores of the resolvers must agree. If the first two resolvers scores do not need to agree, then the system preferably transmits the test item to a third resolver to "cure" the discrepancy in the first two scores. At step 100, the system determines if the third resolver should see the first scores.

FIG. 10 shows additional typical processing of the collaborative scoring. If the original resolvers 1 and 2 must agree on a score, then the system executes steps 101-105. The system then typically first displays to each resolver the other resolver's score at steps 101 and 102 so that each resolver can see the score determined by the other resolver. At step 103, the system establishes a communication between the two resolvers. Such a communication link may be, for example, an electronic mail link so that the scorers can exchange information regarding the reasoning behind the score provided. At step 104, the resolvers work together to determine a single agreed-upon

score for the test item. The system may prevent the  
resolvers 1 and 2 from receiving another test item until  
they have entered an agreed-upon score for the previous  
test item. Finally, at step 105, the system stores the  
5 agreed-upon score in the work-in-process database.

Instead of allowing the resolvers to work together  
to record an agreed-upon score, the system may optionally  
record either a greater value of the first and second test  
scores, a lower value of the first and second test scores,  
10 or an average value of the first and second test scores.

If the collaborative scoring criteria specifies  
that the third resolver should arbitrate the discrepancy  
and determine a score, then the system displays scores from  
the resolvers 1 and 2 at step 106 for resolver 3. The  
15 third resolver (resolver 3) then typically enters a score  
for the test item at step 107, and the system records the  
score in the work-in-process database at step 108.

If the collaborative scoring requirement specifies  
that the third resolver should not see the first two  
20 scores, then the system executes steps 109-111. At step  
109, the system displays the test item for the third  
resolver. The third resolver then typically enters a score  
at step 110, and the system records the score in the work-  
in-process database at step 111.

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#### Quality Items

FIG. 11 is a typical flow chart of the use of quality items in the scoring process. The system can use quality items to check and monitor the accuracy of the scoring for selected test resolvers in order to maintain consistent and high quality scoring of test items. At step 112, the system determines or receives the quality criteria. The quality criteria may be, for example, a predetermined test item with a known "correct" score.

The system then waits for a scheduled quality check at step 113. At the quality check, the system, at step 114, sends the known quality item to the scheduled resolver. At step 116, the system updates the resolver's quality profile based on the evaluation at step 115. If the resolver should receive a quality result, as determined at step 117, the system displays the quality profile to the resolver at step 118. At step 119, the system sends the quality profile to a manager for subsequent review. At step 120, the system takes action required to assure scoring accuracy.

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#### Resolver Monitoring and Feedback

FIGURE 12 is a flow chart of typical resolver monitoring and feedback. The primary factors in monitoring performance typically include: (1) validity; (2) reliability; and (3) speed. In monitoring these factors, the system promotes repeatability of scoring. These

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factors may be monitored by tracking a resolver's performance against past performance of the resolver or against some known goal.

Validity is typically measured by determining if a particular resolver is applying the scoring key correctly to test items or, in other words, scoring test items as an expert would score the same items. Reliability is typically measured by determining if a particular will resolve the same test item the same way over time (providing consistent scoring). Speed is typically measured by comparing a resolver's scoring rate with past scoring rates of the resolver or other scoring rates, such as average scoring rates or benchmark scoring rates.

At step 121, the system typically continually monitors the resolver's performance and updates the performance. Monitoring the resolver's performance may include, as explained above, monitoring the resolver's validity, reliability, and speed in resolving test items. The system periodically, according to predefined criteria, performs performance checks of the test resolvers. Predefined criteria may include, for example: a time period; recalls (how often a resolver evaluates his or her own work); requesting help; the number of agreements among multiple resolvers; the amount of deviation between the resolver's score and a known score, which may be determined using quality items; the frequency of these deviations; the

speed at which a resolver enters a response during resolving of test items; the length of time between scores entered by a test resolver; a test resolver's previous scoring rate, an average scoring rate of a test resolver; 5 average scoring rates of other test resolvers; or some predetermined benchmark scoring rate.

At step 122, the system determines whether it is time for a scheduled performance check according to the predetermined criteria. If it is time for a performance 10 check, the system at step 123 compares the resolvers' current performance, as determined at step 121, with the stored performance criteria. At step 124, the system determines if there is a discrepancy in the resolver's performance according to the predetermined criteria. For 15 example, the system may determine if the resolver's current scoring rate is within a predefined percentage of the average scoring rate in order to ensure efficient scoring by the test resolver. If there is no discrepancy, the system returns to monitoring the resolver's performance. 20 In addition, the system may store the resolver's current performance values for later processing. Otherwise, the system reports the discrepancy at step 125.

At step 126, the system determines if it should recommend a break in scoring to the resolver. If according 25 to predetermined performance criteria, the system should recommend a break in scoring, then the system signals the

resolver at step 128 to halt scoring. Predefined performance criteria may include, for example, deviations in the resolver's validity, reliability, or speed of resolving test items. Examples of predefined performance criteria are provided above with respect to the monitoring of resolvers' performance.

When the resolver stops scoring, the system may provide the resolver with the option of requesting diversionary activities. Diversionary activities are designed to provide the test resolver with a rest period and "break" from scoring to increase efficiency. Examples of diversionary activities include computer games and cross word puzzles. If the resolver has requested such diversionary activities, as determined at step 129, then the system transmits a diversionary activity to the resolver at step 130. Otherwise, the system returns to monitoring the resolver's scoring rate when the resolver resumes the scoring.

If the system at step 126 does not recommend a break in scoring based on the discrepancy, then the system may optionally provide the resolver with diversionary activities as determined at step 127. If the resolver should receive the diversionary activities, then the system sends such activities to the resolver at step 130. Otherwise the system returns to monitoring the resolver's scoring rate.

### On-Line Scoring Guide

FIGURE 13 is a flow chart of a typical on-line scoring guide system. The on-line scoring guide increases  
5 scoring efficiency by allowing the resolver to request scoring rules in order to assist in scoring a particular test item. In response to the request, the system displays scoring rules corresponding to a test question for the test item currently displayed to the resolver. A resolver may  
10 thus quickly have specific scoring rules available on-line while scoring test items. This promotes scoring efficiency and reduces unnecessary break times resulting from determining how to score a particular test item.

At step 131, the system sends a test item to a  
15 resolver for scoring and displays the test item at step 132. If the resolver has requested scoring rules, as determined at step 133, then the system interrogates a stored scoring guide to locate scoring rules that correspond to a test question for the test item currently  
20 displayed to the resolver. The system retrieves those particular scoring rules at step 135 and displays them to the resolver at step 136. The system preferably uses a multi-tasking environment in order to simultaneously display the scoring rules and the test item. At step 134,  
25 the system waits for the resolver to score the test item.



At step 137, the system stores the test score entered by the resolver into the work-in-process storage.

As described above, the present invention is a system that processes test items. The various functions used in processing the test items promote efficient, high quality, and consistent scoring of test items.

While the present invention has been described in connection with the preferred embodiment thereof, it will be understood that many modifications will be readily apparent to those skilled in the art, and this application is intended to cover any adaptations or variations thereof. For example, a different hardware configuration may be used without departing from the scope of the invention and many variations of the processes described may be used. It is manifestly intended that this invention be limited only by the claims and equivalents thereof.